Corn Grain and Liquid Feed as Non-Fiber Carbohydrate Sources in Diets for Lactating Dairy Cows: Production Trial

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Abstract

We hypothesized that adding liquid feed (LF; source of rapidly available sugar) would maintain or improve measures of dairy cattle performance to a greater degree when corn grain is more coarsely ground as compared to finely ground. The more rapidly available source of carbohydrates provided by the LF may compensate for the more slowly degradable carbohydrates of the coarsely ground corn (CGC); therefore, the performance of the dairy cattle provided the LF (Quality Liquid Feeds, Dodgeville, WI) and coarsely ground corn could be comparable to feeding finely ground corn (FGC). The study was conducted on 60 Holstein cows milked twice a day. The cows began the study at 60 days in milk (DIM), where they began a two-week covariate period (fed the FGC diet), followed by random assignment to one of five diets. The five diets were: steam-flaked corn (SFC) (control), FGC, CGC, FGC plus LF, and CGC plus LF. All diets were formulated to contain 16% alfalfa, 24% corn silage, 6% grass hay, and 54% grain. The diets were adjusted to maintain 36% neutral detergent fiber (NDF), 20.3% forage NDF, and 36% non-structural carbohydrates (NSC). For the diets which contained LF, 3.5% of the grain was removed from the diet, and 3.5% of the diet was LF. The FGC + LF and CGC + LF treatments contained 50.5% grain and 3.5% LF. No differences were observed in dry matter intake (DMI) among diets; however, the SFC diet produced the least efficient milk production. Feeding SFC decreased milk fat percentage ($P < 0.10$), and yield ($P < 0.05$). Milk protein yield was similar among diets; however, milk protein percentage was higher for ground corn diets not supplemented with LF ($P < 0.05$). Milk urea nitrogen was lowest for the SFC diet ($P > 0.05$), with no differences among other diets. Observations from this study revealed that

supplementing LF in the diet with either FGC or CGC did not affect the performance of lactating dairy cows.

Introduction and Problem Identification

Increasing the digestibility and rate of degradation of NSC in the diets of dairy cattle can improve rumen microbial activity and forage utilization. The more efficiently rumen microbes ferment the dietary nutrients of the rumen, the more efficiently milk can be produced (Firkins et al., 2001). Research by Callison et al. (2001) has revealed that decreasing the particle size of corn can effect the digestibility of NSC. However, increasing the digestibility and degradation of the NSC from corn in the rumen requires processing, which comes at a price to dairy producers. Firkins et al. (2008) found that supplementation of LF with a white grease product increased milk production, milk fat percentage, and milk protein percentage. Supplementing CGC with LF could compensate for the slow degradability of the NSC of corn, and offer an alternative to using finely ground corn in lactating dairy cow diets.

The focus of this research was to determine whether supplementing LF in diets with finely and coarsely ground corn could offer an alternative to the highly processed corn grain, SFC, without limiting animal performance. By comparing the performance of animals given either finely or coarsely ground corn, with or without supplementation of LF, conclusions pertaining to the amount of grain processing can also be made. If feeding CGC supplemented with LF results in similar performance measures as a finely ground corn diet, corn fed to lactating dairy cattle could be processed less, reducing cost of processing, while still offering the same production of milk.

We proposed that the addition of LF to a diet with CGC could offer similar production measures of a more processed corn grain, such as steam-flaked corn or more finely ground corn. We proposed that the liquid feed would compensate for the more slowly degradable NSC present in CGC by offering more readily available energy for microbial fermentation of feedstuffs, without impacting DMI, milk production, milk fat, and milk protein.

Hypothesis

The hypothesis of the experiment was that sugars in LF will maintain or improve measures of dairy cattle performance to a greater degree when corn grain is coarsely compared to finely ground.

Procedures and Methodology

Sixty Holstein cows from The Ohio State University's Waterman Dairy Center were used during this research project. A parallel study, conducted by other department researchers, was conducted using 5 rumen cannulated dairy cows in a 5 x 5 Latin square during which the diets fed were the same as used in this experiment. The study with cannulated cows examined ruminal fermentation characteristics and digestibility.

Cows began the trial after they had been in milk at least 06 days. The cows immediately began their two week covariate diet, which was the FGC diet. After the covariate diet was fed for two weeks, the cows were blocked by parity, previous lactation milk yield, and date of calving and assigned to 1 of 12 blocks. Within each block, cows were randomly assigned to one of the five diets. The diets consisted of 24% corn silage, 16% alfalfa hay, 6% grass hay, and 54% grain (Table 1). The diet was adjusted to maintain 36% NDF; therefore, the proportion of alfalfa and grass hay fed varied throughout the trial, but averaged 20% for the alfalfa and 2% for the grass hay. The concentrate portions of the non-LF supplemented diets contained 54% concentrate. The LF supplemented diets had 3.5% less grain, with 3.5% LF added. The LF was 66% dry matter. On a dry matter basis, the LF contained 30.3% protein and 53% total sugar; therefore the LF were expected to provide 1.86% supplemental sugar to the diets containing the LF.

Table 1. Ingredient composition of diets (% of DM).[1]

Item	SFC	FGC	CGC	FGC + LF	CGC + LF
Corn Silage	24.0	24.0	24.0	24.0	24.0
Alfalfa Hay[2]	16.0	16.0	16.0	16.0	16.0
Grass Hay[2]	6.0	6.0	6.0	6.0	6.0
Concentrate	54.0	54.0	54.0	50.5	50.5
LF	0.0	0.0	0.0	3.5	3.5

[1]SFC=Steam flaked corn, FGC= finely ground corn, CGC=coarsely ground corn, and LF=liquid feed.
[2]Amounts of alfalfa and grass hay were adjusted to maintain NDF at 36%.

The cows were housed in tiestalls at The Ohio State University's Waterman Dairy Complex. Cows were milked twice a day at 0500 and 1700h in a double-8 herringbone parlor. Feed was mixed in the evening, after refusals had been collected and weighed.

The cows were fed at 110% ad libitum intake, and feed was offered twice a day. The total mixed ration (TMR) and refusal samples were sampled during weeks 4, 8, and 12 of the trial for analysis of sorting using a three-screen Penn State Particle size separator. The TMR samples were also taken weekly for analysis of DMI. Milk samples were taken for four consecutive milkings weekly and analyzed for milk fat and protein percentages, and milk urea nitrogen (MUN) at DHI Cooperative, Inc (Columbus, OH). Weighted averages for milk fat and protein percentages were calculated using the daily production data. Body weights were taken weekly. Body condition scores (BCS) were taken at the beginning of the covariate period, at the beginning of the treatment diet, and during weeks 4, 8, and 12 of the treatment period. The DM analysis of corn silage was taken weekly and adjustments were made in the diets. Monthly samples of the alfalfa and grass hay were taken to adjust NDF concentrations to the target 36% NDF. Concentrates were sampled weekly and new shipments of SFC were sampled upon arrival. Forages and concentrates were analyzed in the ruminant nutrition lab within the Department of Animal Sciences at The Ohio State University.

The data were analyzed as a randomized complete block design with block as a random effect. Repeated measures (dependent variables by week) were analyzed using PROC MIXED (SAS, 2004), cow within diet and block as the SUBJECT, and the autoregressive (AR(1)) covariance structure was used for all data except the concentrations of milk components for which compound symmetry was used. No diet by week interactions ($P < 0.10$) occurred except for BW ($P = 0.10$), and this is not discussed given that there were no differences among treatments for BW change.

Results and Discussion

Only 54 cows were used in the study, rather than the target of 60. Cows were removed from the study due to health problems or death unassociated with the treatment diets. Data were collected with 11 cows per treatment, with 10 cows used in the FGC + LF diet. Twenty-six cows within the study were primiparous and 28 were multiparous.

The study conducted parallel to this one examined the digestibility of the various corn grain (Table 2)(Eastridge et al., 2011). From the results listed, the A pool values were lowest for the CGC, which is expected due to the larger particle size; however, the B pool of the CGC is higher than values of the B pool for the other two corn varieties. The FGC had the largest A pool. The rates of degradation (Kd) for the corn varieties were similar; however, ruminal degradation differed among them. Ruminal degradation values listed from highest to lowest were: FGC, SFC, and CGC.

Table 2. In situ DM digestibility of steam flaked corn (SFC) and coarsely and finely ground corn (CGC and FGC, respectively).[1]

Corn Grain	A pool (%)	B pool (%)	C pool (%)	Kd (/h)	RD (%)	Lag (h)
SFC	11.51[c]	85.0[b]	3.52	0.043	50.1[c]	0.00[b]
FCG (0.8 mm)	15.42[b]	83.1[b]	1.45	0.057	53.6[b]	2.27[a]
CGC (1.9 mm)	6.08[a]	91.1[a]	2.82	0.052	43.1[a]	2.94[a]
SEM	1.17	1.9	1.31	0.005	0.9	0.32

[abc]Means in the same column differ ($P < 0.05$).
[1]Kd= Rate of degradation and RD = extent of ruminal degradation.

Analysis of the diets was generally similar to target values. However, the protein percentage was 92% of the target value. Due to the high DMI observed, adequate protein was still provided in the diets. The percentage of starch in the corn silage was also lower than expected. The NDF values of the diets were similar to the target of 36%; however, the diets did vary from 34 to 38%. Starch was similar among diets without supplemental LF. Since 3.5% of the grain was removed for the diets containing LF, starch concentrations for the LF diets were lower than the other diets.

Table 3. Chemical composition of diets and forages fed.[1]

Item	SFC	FGC	CGC	FGC + LF	CGC + LF
DM, %	65.2	64.7	63.9	65.4	65.3
CP, %	16.2	16.3	17.0	16.7	17.4
NDF, %	38.3	36.0	37.0	34.4	38.7
Starch, %[2]	17.4	19.7	17.5	15.2	14.3
Ash, %	7.08	6.45	6.94	7.03	7.10
Forages					
	Corn Silage		Alfalfa Hay		Grass Hay
DM, %	34.0		90.1		91.5
CP, %	6.60		19.22		10.16
NDF, %	48.9		39.3		63.2
Starch, %	20.2		---		---

[1]SFC = Steam flaked corn, FGC = finely ground corn, CGC = coarsely ground corn, and LF = liquid feed.
[2]Calculated based on proportion of grain and corn silage in diets and analytical value for starch.

The performance measures of the dairy cattle obtained during this study can be found in Table 4. Dry matter intake did not appear to change among diets. Body weight and BW change were similar among the diets fed. Body condition score tended to be the lowest ($P < 0.10$) for the liquid feed diet, as compared to the other diets. However, there is likely no physiological significance of this finding. The body condition score change per four weeks was also similar among diets.

Milk production was not affected by diet as well; however, with a tendency for a decrease in milk fat percentage and decrease in milk fat yield for the SFC diet, fat corrected milk (FCM) was lowest for cows. The SFC diet decreased milk production efficiency on a FCM/DMI basis ($P = 0.01$). This change in milk fat production is likely due to an increase in propionate and decrease in acetate:proprionate ratio as found with the parallel study examining rumen characteristics associated with the diets fed (Eastridge et al., 2011). Milk protein percentage was lowest for both diets supplemented with LF ($P < 0.01$); however, total protein yield was similar for all diets, likely due to the slight increase in total milk yield for the LF supplemented diets. Milk urea nitrogen was lowest for the SFC diet ($P < 0.05$). This is attributed to a decrease in ruminal ammonia concentrations by the parallel study examining ruminal characteristics (Eastridge et al., 2011).

Table 4. The DMI and animal performance by cows fed steam-flaked corn and two particle sizes of ground corn with and without a sugar source.[1]

Item	Diets[1]					SEM	Contrasts[2]			
	SFC	FGC	CGC	FGC + LF	CGC + LF		SFvGC	PS	LF	PS x LF
DMI, kg/d	26.3	25.3	25.8	26.2	25.5	0.5	0.33	0.89	0.64	0.27
BW, kg	613	614	612	611	608	4	0.59	0.42	0.27	0.99
BW change, kg/wk	3.07	3.82	2.77	3.57	2.62	0.73	0.88	0.18	0.79	0.95
BCS	2.31	2.42	2.57	2.33	2.37	0.09	0.21	0.24	0.06	0.48
BCS, change/4 wk	0.11	0.15	0.13	0.10	0.15	0.04	0.61	0.73	0.75	0.36
Milk, kg/d	38.7	40.1	38.9	40.8	40.2	0.8	0.14	0.26	0.20	0.74
3.5% FCM, kg/d	38.3	41.1	39.8	39.7	40.7	1.1	0.03	0.84	0.77	0.14
FCM/DMI, kg/kg	1.45	1.62	1.54	1.54	1.56	0.04	0.01	0.34	0.29	0.15
Milk fat, %	3.22	3.61	3.45	3.40	3.38	0.11	0.06	0.44	0.22	0.52
Milk fat, kg/d	1.29	1.45	1.38	1.37	1.40	0.05	0.01	0.63	0.38	0.18
Milk protein, %	2.90	2.90	2.90	2.81	2.80	0.04	0.24	0.88	0.01	0.99
Milk protein, kg/d	1.15	1.17	1.15	1.14	1.15	0.02	0.90	0.82	0.38	0.30
MUN, mg/dl	12.0	13.3	12.9	12.9	13.2	0.5	0.04	0.88	0.99	0.48

[1]SFC = Steam flaked corn, FGC = finely ground corn, CGC = coarsely ground corn, and LF = liquid feed.
[2] SFvGC = corn processing, steam-flaked versus ground corn (SFC vs FGC, CGC, FGC + LF, CGC + LF); PS = particle size (FGC, FGC + LF vs CGC, CGC + LF); LF = Liquid feed (FGC, CGC vs FGC + LF, CGC + LF); and PS x LF = interaction particle size and liquid feed.

The addition of LF has been shown to conglomerate smaller particle sizes when incorporated into a TMR (Oelker et al., 2009). With a higher dietary DM percentage than usual for TMR, the risk for sorting should have been high. However, our trial has shown that the incorporation of LF had no effect on the sorting index (Figure 1). The sorting index used in this trial was developed by Zebeli et al. (2009). Sorting against larger particles was present in all diets, and the sorting index increased as particle size decreased.

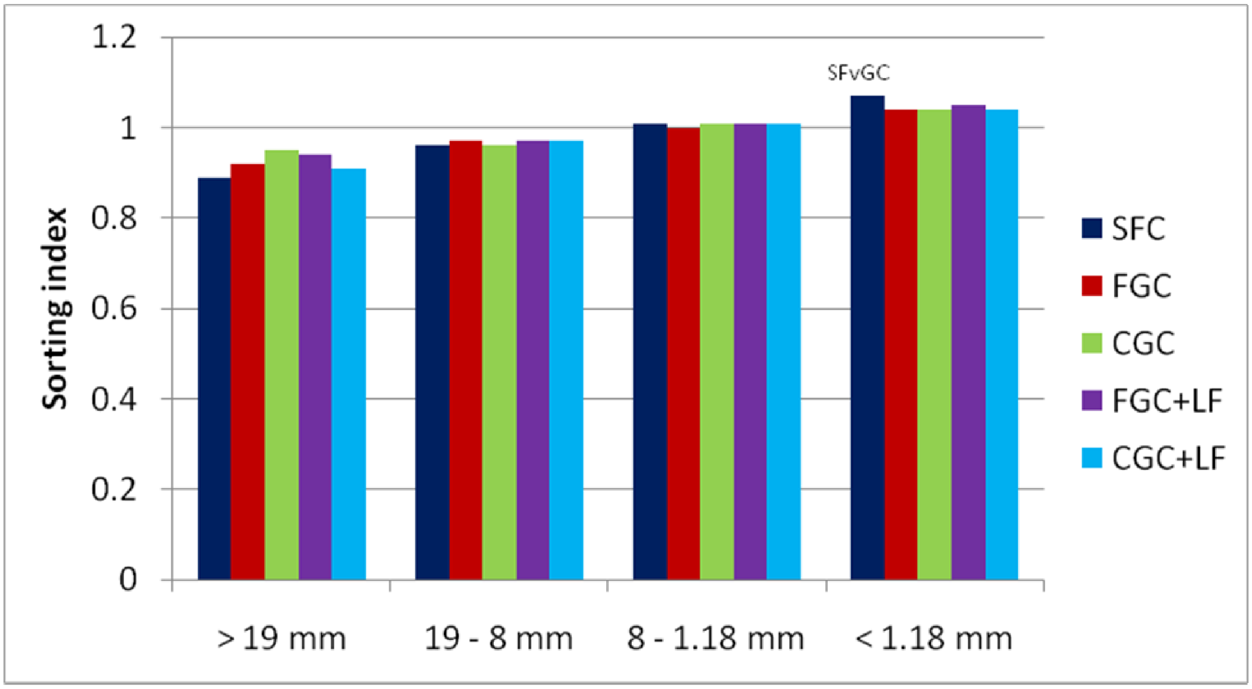

Figure 1. Sorting index (1 = no sorting, <1 sorting against, and >1 sorting in favor) for cows fed steam-flaked corn and two particle sizes of ground corn with and without a sugar source (SFC = steam flaked corn; FGC = finely ground corn; CGC = coarsely ground corn; and LF = liquid feed); SFvGC = corn processing, steam-flaked versus ground corn (SFC vs FGC, CGC, FGC + LF, CGC + LF), *P* < 0.01.

Conclusions and Implications

We could not accept the hypothesis that CGC with LF would maintain or improve the performance of lactating dairy cattle than FGC. We did, however, provide data that supports that LF can be supplemented into diets containing either finely or coarsely ground corn without detrimental effects. Milk protein percentage was slightly decreased with the addition of LF to the diet; however, with a slight numerical increase in milk yield observed by the supplemented LF, total milk protein yield was unaffected. Therefore, LF may serve as an alternative to more processing of corn (such as SFC) without adversely affecting the performance of dairy cattle.

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